N90-27845

THE EFFECTS OF SPACE RADIATION ON THIN FILMS OF $YBa_2Cu_3O_{7-x}$

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High temperature superconducting materials are expected to offer significant improvements in the performance of spacecraft components. Specifically, low surface resistance at high frequencies is expected to result in reduced RF losses in superconducting waveguides, bandpass filters, and antennas. The broader bandwidth response of these materials may lead to improved and more sensitive IR detectors. The ability to exclude outside magnetic fields will result in high quality EMI-shielded enclosures, and the absence of resistive losses may lead to superconducting batteries with improved energy density and round-trip efficiencies.

It is attractive to provide passive cooling to superconductors by locating them on the shaded side of a space vehicle, radiating directly into space. Unfortunately, the technique results in exposure to high radiation dose levels due to trapped electrons and protons in the space environment. The high energy electrons and the protons will lose most of their energy in the first few microns inside the surface. For example, a typical surface dose for a 5-year mission in low earth atmospheric remote sensing orbit is 10^{15} electron/cm^2 which deposits 10 Megarads (10^9 ergs/gram) of energy in surface material. This is two or three orders of magnitude higher than the dose to most satellite electronics, which are shielded by at least several millimeters of material. The effects of space radiation on superconducting properties of YBCO materials are therefore critically important in incorporating these materials into spacecraft systems. The effects of charged particle irradiation on surface morphology of superconducting thin films has been published (1-3).

This investigation had two objectives: (1) to determine the effects of space radiation on superconductor parameters that are most important in space applications and (2) to determine whether this effect can be simulated with Co-60 gamma rays, the standard test method for space materials.

Thin films of YBCO were formed by coevaporation of Y, BaF_2, and Cu and post-annealing in wet oxygen at 850°C for 3.5 h. The substrate used was (100) silicon with an evaporated zirconia buffer layer. Processing and microstructure studies of these types of films have been published (4-7). The zero-resistance transition temperatures of the samples used in this study were 84 to 86K. The samples were characterized by four point probe electrical measurements as a function of temperature. The parameters measured were: the zero resistance transition temperature (T_c) and the room temperature resistance. The samples were then exposed to Co-60 gamma-rays in air and in pure nitrogen, and to 780-keV electrons, in air. The parameters were then remeasured. The results are summarized in Tables 1 and 2.

The results indicate little or no degradation in the parameters measured for samples exposed up to 10 Mrads of gamma-rays in nitrogen. However, complete degradation of samples exposed to 10-Mrad in air was observed. This degradation is preliminarily attributed to the high level of ozone generated in the chamber by the gamma-ray interaction with air. Furthermore, no degradation in superconducting properties of samples exposed to 10^{15} electrons at 780 kev in air was observed. Apparently these samples are more radiation resistant than the bulk materials which were degraded by exposure to 6.5 x 10" electrons/cm^2 at 1 Mev (Ref. 8).

It can be concluded that (1) the electron component of space radiation does not degrade the critical temperature of the YBCO films described herein, at least for energies around 800 KeV and doses similar to those received by surface materials on spacecraft in typical remote sensing missions; (2) for qualifying this and other superconducting materials against the space-radiation threat the standard test method in the aerospace industry, namely, exposure to Co-60 gamma rays in air, may require some further investigation. As a minimum, the sample must be either in vacuum or in positive nitrogen pressure.

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TABLE 1. SUMMARY OF GAMMA-RAY EXPOSURES ON SUPERCONDUCTING MATERIALS

SAMPLE DESCRIPTION	AMBIENT ENVIRONMENT	GAMMA-RAY DOSE (Mrad)	TRANSITION TEMPERATURE(K)		COMMENTS
			BEFORE EXPOSURE	AFTER EXPOSURE	
1a) YBaCuO on Si	Air	10	86	-	Catastrophic Failure
1b) YBaCuO on Si	Air	100	85	-	Complete erosion of superconducting film
2a) YBaCuO on Si	Nitrogen	10	85	84	Slight degradation in Tc
2b) YBaCu on Si	Nitrogen	10	86	82	Slight degradation in T_c
3) YBaCuO on Si (Control Sample)*	Air	--	85	85	No degradation in Tc (after 21 days)

* The control sample was placed outside of the Co-60 source and its superconducting properties were compared to the exposed samples.

TABLE 2. SUMMARY OF ELECTRON EXPOSURES ON SUPERCONDUCTING MATERIALS

SAMPLE TYPE	AMBIENT ENVIRONMENT	ELECTRON DOSE	TRANSITION TEMPERATURE(K)		COMMENTS
			BEFORE EXPOSURE	AFTER EXPOSURE	
1) YBaCuO on Si	Air	10^{15} electron/cm^2 at 780 kev	84	84	No degradation in Tc
2) YBaCuO on Si (Control Sample)*	Air	-	85	85	No degradation in Tc

* The control sample was placed outside of the electron generator and its superconducting properties were compared to the exposed samples.